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MEMORANDUM REPORT No. 948

NOVEMBER 1955

Aerodynamic Properties Of The 2.75-Inch Rocket T131

[redacted]

L. C. MacALLISTER

W. K. ROGERS, JR.

DEPARTMENT OF THE ARMY PROJECT No. 5B03-03-001
ORDNANCE RESEARCH AND DEVELOPMENT PROJECT No. TB3-0108
TU2-9

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B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

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A B E R D E E N   P R O V I N G   G R O U N D ,   M A R Y L A N D

TABLE OF CONTENTS

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

MEMORANDUM REPORT NO. 948

LCMacAllister/WKRogers,Jr./mlu
Aberdeen Proving Ground, Maryland
November 1955

AERODYNAMIC PROPERTIES OF THE 2.75-INCH ROCKET T131

ABSTRACT

A free-flight range firing program was conducted to determine the aerodynamic properties of the 2.75-inch rocket, T131, between the Mach numbers of 0.72 and 2.3. The firings were made with 2.75-inch rockets with inerted motors and, at higher velocities, with 75mm scale models.

A few rounds of live rockets were also fired. These firings were done largely to test the ability of the Range instrumentation to record the trajectory of a live rocket. The experiment was successful and photographs are included, but the data are not analysed in this report.

TABLE OF SYMBOLS

ρ	=	air density
v	=	flight velocity
M	=	Mach number
d	=	projectile diameter or caliber
A	=	axial moment of inertia
B	=	transverse moment of inertia
δ	=	angle of yaw
$\overline{\delta^2}$	=	mean squared yaw for observed trajectory (deg^2)
η	=	transverse angular velocity
ν	=	axial spin-rad/cal

Ballistic Coefficients

K_D	=	Drag force/$\rho v^2 d^2$
K_M	=	Yaw moment/$\rho v^2 d^3 \delta$
K_L	=	Lift force/$\rho v^2 d^2 \delta$
K_H	=	Yaw damping/$\rho v d^4 \eta$
K_T	=	Magnus moment/$\rho v d^4 \nu \delta$
K_F	=	Magnus force/$\rho v d^3 \nu \delta$

1. INTRODUCTION

At the request of Redstone Arsenal, free-flight tests to determine the aerodynamic properties of the 2.75-inch rocket projectile, T131, inert and live, were made in the Transonic Range of the Exterior Ballistics Laboratory. The program included the thirty-four 2.75-inch rockets with inert motors; ten rockets with live motors; and nine 75mm models of the T131 rocket shape, to cover the higher velocities.

The main purposes of the program were:

a. To determine the drag force, normal force, pitching moment, damping moment, and Magnus moment for the T131 shape for the expected range of flight velocities of the T131 rocket;

b. To obtain measurements of the trajectory of the burning rocket and shadowgraphs of the flow field about the rocket in order to provide data for future investigations.

Redstone Arsenal furnished the launching tube, special cases, and the projectiles for the main program. Material for a supplemental test program with the 2.75-inch rocket was obtained at Aberdeen Proving Ground and at the Army Chemical Center.

2. FIRING PROGRAM

The program, as outlined in Table I, is essentially divided into the firing of three types of projectiles:

a. 2.75", Rockets with inert motors,
b. 2.75", Rockets with live motors,
c. 75mm Models of 2.75", T131, Rocket.

The above projectiles, except those necessary for the proof testing of the live rockets and the 75mm models, were fired through the instrumentation of the Transonic Range. The Range[1] is an enclosed firing tunnel (Fig. 1) 680 feet long with photographic instrumentation. The stations record the position, attitude, and time of flight of the projectile to an accuracy of .01 feet in distance, 0.1 degree in angular measurement, and 1 microsecond in time.

The station records are shadowgraphs: the shadow of the rocket is cast on a beaded screen by a short-duration spark source and simultaneously photographed by a camera displaced from the spark source by a distance of 2.5 feet. This separation is necessary to prevent the luminosity of the actual rocket trail from fogging the region of the plate which contains the shadow of the projectile. A schematic diagram of a shadowgraph station is shown in Figure 11 and a more complete description of the general instrumentation is given in Reference 1. Figures 12, 13, 14, and 15 are a series of shadowgraphs from the range stations. The physical properties of the projectile are given in Table 2.

The HE rocket, the T131, could not be used in the range test and the program was actually carried out with T132 practice rockets with inert heads. The rockets are ballistically the same.

2.1 2.75" Rockets with Inert Motors

The inert Rockets (Fig. 2) were launched from a 1/12 twist launcher furnished by Redstone Arsenal (Fig. 3). The launcher was mounted on a 155mm howitzer carriage. The initial firings having produced insufficient yaw to yield a satisfactory data reduction, a blast deflector was attached to the muzzle to induce yaw (Fig. 4). The rounds were launched in a normal manner with only the booster charge. The projectile was enclosed in a case which was loaded into the opening in the side of the launcher breech (Fig. 5); positioned and held in place by pressure from the firing mechanism. The test velocity range covered was $.73 \leq M \leq 1.12$. In one instance a charge was stored overnight at an elevated temperature and a Mach number of approximately 1.16 was obtained. All shell successfully traversed the range instrumentation. Prints of two of the shadowgraphs of 2.75" Rocket projectiles in free-flight are shown in Figs. 9 and 10.

2.2 2.75" Rockets with Live Motors

The live 2.75", Rockets were fired from the semi-closed breech launcher with both booster and live rocket motor. Again difficulty was encountered with insufficient yaw for data reduction and the blast deflector was again employed successfully. Also the booster charge was

lowered on two of the rounds in an attempt to induce greater yaw. It was thought that if the projectiles emerged into the region of the blast deflector at very nearly sonic velocity some gain in yaw might be realized. Only small effects were noted.

2.3 75mm Model 2.75", T131, Rocket

The scale models (Fig. 6) for the 75mm firings were not usable as received, because the rotating bands were inadequate for this experiment. Stability computations based on the measured moments of inertia and the first available overturning moment data of the 2.75" program at higher Mach numbers also indicated that the stability factor for firings from the proposed gun (75mm M1917, 1/25 twist, or equivalent) was probably marginal.

The first 75mm models used were modified by pinning the existing band to the shell with stell pins. These models were then launched from a 75mm M6 gun, with a 1/25 twist. One round was successfully fired through field instrumentation, although the yaw level appeared high. Three similar rounds were subsequently launched through the range instrumentation.

One of the three shell flew in a fairly acceptable manner, although the yaw level was higher than desired, and the data indicated that it had full spin. In the second case the shadowgraphs indicated that the projectile had a damaged band and had a yaw level much too high for reduction purposes. Consequently, efforts to launch these 75mm projectiles ceased, and new, stronger bands were manufactured for the remaining models (Fig. 7). Four projectiles were pre-engraved at 1/20 twist for launching from the 75mm M1A3 Howitzer (Fig. 8). The twist of the Howitzer tube was sufficient to ensure adequate model stability but the strength of the tube was not sufficient to launch the models at the higher velocities. Hence, the two remaining models with the strengthened band were pre-engraved for the 1/25 twist for the M6 gun.

The Howitzer firings were generally successful but the projectiles launched from the gun produced unsatisfactory data because the yaw level was too high to yield a reliable reduction.

3. EXPERIMENTAL RESULTS

In general, the program yielded good data on the T131 shape from velocities of about 800 to 1300 feet per second. The data obtained with the 75mm models above 1300 fps are so sparse and so contaminated with minor configurational changes and high yaw levels that, at best, they furnish only an indication of the trends of the aerodynamic properties up to 2500 fps.

The 75mm models did not have model rocket nozzles on the base. Since these nozzles are enclosed by the wake, their absence would not be expected, under ordinary circumstances, to alter the aerodynamic properties. However, the wake formation of this shell varied from round to round; variations of wake angles up to 8° were observed. This variation could be expected to produce a marked effect on the drag of the shell and might also alter other properties. The aerodynamic data, as obtained from the reductions,[2] are tabulated in Table 4.

3.1 Drag

The variation of the drag coefficient, K_D, for $0.7 \leq M \leq 1.2$ is given in Graph 1. This plot is based on the 2.75" inert rocket firings. Graph 1a includes the data from the 75mm ballistic slugs and only a trend is established. These latter data indicate that variations of K_D of up to 0.01 might be possible due to different base pressures; and that the yaw drag coefficient, $K_{D_{\overline{\delta^2}}}$, defined as $K_D = K_{D_o} + K_{D_{\overline{\delta^2}}} \cdot \overline{\delta^2}$, is about 0.0007 per degree squared at supersonic speeds.

3.2 Yaw and Moment Lift

The yaw moment coefficient, K_M, is plotted as a function of Mach number for the inert 2.75" data in Graph 2 and for all the firings in Graph 2a. The variation of K_M with Mach number of the 75mm models is fairly consistant with the 2.75" inert rockets. The model data are more ragged but do not exhibit large differences even for the extreme variations of yaw level encountered.

The 75mm data are consistently higher than might be expected by extrapolating the 2.75" data. Since the center of mass positions for both model sizes are nearly the same (1.77 ± .01 cal from the base), the difference appears to be due to a minor difference in external shape of the 2.75" rocket and its 75mm model. However, the only marked differences were a slightly more forward position of the rotating band and more clean cut contours for the 75mm models.

The lift coefficient, K_L, is given in Graphs 3 and 3a. Fairly large variations appear which seem to be due to yaw level.

3.3 Magnus Moment and Force

The Magnus moment coefficient, K_T, changes sign at about Mach number 1.2. It is positive and fairly constant at a level of about 0.1 subsonically and of the same order of magnitude but negative above M = 1.3. Unfortunately the cross over occurs between the data from the 2.75" inert rocket and the 75mm model. In this case, however, the data from the former definitely indicates such a trend[1]. K_T appears fairly insensitive to yaw level and is plotted in Graphs 4 and 4a.

The Magnus force coefficient, K_F, is poorly determined even for the 2.75" projectiles. The better values indicate a general level of 0.15 for the speeds tested.

3.4 Damping Moment

The damping moment coefficient, K_H, is plotted in Graph 5 for the 2.75" data. The value of the coefficient rises from a level of 1.5 subsonically to about 3.5 at M = 1.1. The indications from the 75mm data are that K_H maintains this, or a slightly higher level, up to a Mach number of 2.2.

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1 Reference 3 indicates that the difference in spin level between the 2.75" and 75mm models could cause a small difference in K_T. From the 5 caliber long models of this reference the value of K_T of the 75mm models should be raised by 0.044 at M = 1.3.

4. APPENDICES

4.1 Supplemental Program

4.2 Table 1 Firing Program

Table 2 Physical Measurements

Table 3 Supplemental Firing Program

Table 4 Aerodynamic Data

Table 5 Supplemental Data 2.75" Rocket

4.3 Graph 1 2.75" Inert Rocket K_D vs M

Graph 2 K_M V_s M

Graph 2a K_D vs M

Graph 3 K_L vs M

Graph 4 K_T V_s M

Graph 4a K_L vs M

Graph 5 K_H vs M

4.4 Figure 1 Interior of Transonic Range

Figure 2 2.75" Projectile

Figure 3 Rocket Launcher Mounted on 155mm Howitzer Carriage

Figure 4 Rocket Launcher With Blast Deflector on Muzzle

Figure 5 Close-Up, Launcher Breech

Figure 6 75mm Ballistic Slug of the T131 Rocket Shape

Figure 7 Modified 75mm Ballistic Slug

Figure 8 75mm M1A3 Howitzer

Figure 9 Rocket in Free-Flight (Round Number 2494), Velocity: Approx. 1115 ft/sec, Mach number: Approx. .99

Figure 10 Rocket in Free-Flight (Round number 2487), Velocity: Approx. 1280 ft/sec, Mach number: Approx. 1.14

Figure 11 Schematic Diagram of Range. Set-up For Live Rocket Spark Photograph

Figure 12 Rocket in Burning Flight (Round Number 2506) Distance in Launcher: Approx. 102 ft., Velocity: Approx. 1205 ft/sec., Mach number: Approx. 1.07

Figure 13 Rocket in Burning Flight (Round Number 2506) Distance from Launcher: Approx. 232 ft., Velocity: Approx. 1440 ft/sec., Mach number: Approx. 1.28

Figure 14 Rocket in Burning Flight (Round Number 2506) Distance from Launcher: Approx. 612 ft., Velocity: Approx. 1875 ft/sec., Mach number: Approx. 1.67

Figure 15 Rocket in Burning Flight (Round Number 2506) Distance from Launcher: Approx. 722 ft., Velocity: Approx. 2036 ft/sec., Mach number: Approx. 1.81

4.5 References

4. APPENDICES

4.1 Supplemental Program: 2.75" Rocket With Inert Motor

The two sizes of models used in the basic program were fired in two distinct Mach number ranges: $0.7 \leq M \leq 1.13$ for the 2.75-inch projectile and 1.2 M 2.2 for the 75mm models. A preliminary evaluation of the data showed that some of the aerodynamic properties changed markedly between the end of the 2.75-inch projectile data and the beginning of the 75mm model data. These changes might be ascribed to the different model sizes and minor shape variations, or, to a sudden change of the aerodynamic properties with Mach number between M = 1.13 and 1.2.

To establish the cause of the variation in these properties, nine additional rockets were obtained and fired. The shell were lightened by removing the inert loading from the heads, or tails, in order to obtain higher velocities. This modification was only slightly effective in achieving higher speeds. It did result, however, in a higher data population at the upper Mach number end of the 2.75-inch data.

The program is given in Table 3 and the data in Table 5. The data points are also plotted on the pertinent Graphs of the main report. It should be noted that the process of lightening the shell also changed the physical properties (center of mass, etc.) and where possible the plotted data have been corrected to the c.g. position of the main program.

4.2 TABLE 1

FIRING PROGRAM

Range Rd.No.	Phys. Meas. No.	Booster Powder Charge oz	Powder Lot No	Approx. Mid Range Velocity	Launcher	Remarks	Redstone No.
2478		6.15	P12564	1025	Semi-closed rocket launcher	very small yaw	6
2479		7.00	"	1148	"		1
2480		7.50	"	1217	"	" " "	2
2481		7.50	"	1220	"	" " "	3
2482		6.15	"	1028	"	" " "	7
2483		5.25	"	813	"	" " "	4
2484		7.00	"	1185	"	1 inch of grease in one corner of muzzle	14
2485		6.00	"	1015	"	with muzzle extension notched	18
2486		7.50	"	1245	"	" " "	20
2487		7.50	"	1270	"	" " "	16
2488		5.75	"	990	"	" " "	5
2489		5.50	"	947	"	" " "	21
2490		5.35	"	950	"	" " "	25
2491		7.00	"	1203	"	" " "	28
2492		7.00	"	1210	"	" " "	24
2493		6.55	"	1124	"	" " "	22
2494		6.55	"	1116	"	" " "	27
2495		6.25	"	1036	"	" " "	19
2496		6.25	"	1098	"	" " "	26
2497		5.35	"	938	"	" " "	29
2498		6.25	"	1063	"	" " "	23
2499		6.75	"	1123	"	" " "	15
2500		6.82	"	1171	"	" " "	13
2501		4.80	"	824	"	" " "	12
2502	305B	7.50	"	1300	"	heated in hot box 90° prior to firing	11
2503		6.15-06	"		"	live rocket thru yaw cards	
2504		"	"		"	" " "	
2505		"	"		"	" " "	

TABLE 1 (CONT)
FIRING PROGRAM

Range Rd.No.	Phys. Meas. No.	Booster Powder Charge oz	Powder Lot No	Approx. Mid Range Velocity	Launcher	Remarks	Redstone No.
2506		6.15-06	P12564		Semi-closed rocket launcher	live rocket thru range (little yaw)	
2507		"	"		"	" " "	
2524		"	"		"	live rocket thru field yaw cards (with yaw inducer)	
2525		"	"		"	" " "	
2526		"	"		"	" " "	
2527		6.25-06	"		"	live rocket thru range (with yaw inducer)	
2528		5.25	"		"	" " "	
2529		30.50	P3986	2257	75mm Gun M6 (1/25)	ballistic slug-field	Note *
2530		"	"	2190	"	" range	7 Note *
2531	310B	35.00	"	2422	"	" "	2 Note *
2532		38.00	"	2585	"	" "	9 Note *
2574		15.36	P15500	1391	75mm Pack (M1A3) Howitzer (1/20)	" "	1 Note **
2575		21.59	"	1862	"	" "	Note **
2576		17.60	"	1536	"	" "	Note **
2577	332B	20.48	"	1772	"	" "	3 Note **
2578		37.00	P3986	2451	75mm Gun M6 (1/25)	" "	Note **

* Redstone rotating band (pinned at APG) magnet inserted and pin in base

** APG band, Magnet inserted, pin in base.

4.2 TABLE 2

PHYSICAL MEASUREMENTS

Redstone No.	Phys. Meas. No.	WT lbs	Inches c.g. from base	Inches Length	A $lb\text{-}in^2$	B $lb\text{-}in^2$	Angle of Nozzle
2.75" Rockets							
11	305B	5.346	4.781	12.643	5.701	57.55	
10	306B	5.271	4.859	12.648	5.675	56.07	
8	307B	5.348	4.919	12.657	5.700	56.55	
9	308B	5.273	4.856	12.648	5.698	56.27	11°55' 12°4'

75mm Ballistic Slugs

* 5	309B	7.2900	5.263	13.538	7.327	80.39	
* 2	310B	7.3098	5.262	13.536	7.342	80.80	
* 3	311B	7.2855	5.263	13.535	7.319	80.27	
** 2	321B	7.6707	5.190		7.375	81.34	
** 5	319B	7.6641	5.196		7.374	81.46	
** 3	320B	7.6652	5.195		7.367	81.35	
*** 3	332B	7.8748	5.223		7.799	87.86	pins

* Originally measured as recieved.

** Remeasured with steel pins in band, magnet inserted and pin in base.

*** Remeasured again with APG band.

Supplemental Models, 2.75" Rockets

Head Empty		4.319	4.179		5.048	43.28	
Tail Empty		3.979	5.471		4.497	48.12	

4.2

TABLE 3

SUPPLEMENTAL FIRING PROGRAM

Range Rd.No.	Phys. Meas. No.	Booster Powder Charge oz	Powder Lot No	Approx. Mid Range (velocity)	Launcher	Remarks
			PAE			Yaw inducer used on all rounds.
3385		7.50	T30213177	1274	Semi-closed rocket launcher	Head Empty Hit Station 3-3 Coil
3386	427B	"		1264	"	"
3387	428B	"		1300	"	Motor Empty
3388	429B	"		1304	"	"
3389		"		1335	"	Head Empty
3390		"		1293	"	Motor Empty
3391		"		1252	"	"
3392		"		1250	"	"
3393		"		1267	"	"

4.2 TABLE 4

Round No.	M	$\overline{\delta^2}$	K_D	K_M	K_L	K_H	K_T	K_F	Size (dia)
2501	0.718	18.3	0.1143	1.194	0.78	1.58	0.087	--	2.75"
2483	0.72	0.8	0.1004	0.97*	0.76*	1.64*	0.045*	--	"
2497	0.816	24.7	0.1154	1.22	0.76	1.65	0.088	--	"
2489	0.828	15.2	0.1136	1.23	0.76	1.52*	0.081*	0.14	"
2490	0.834	10.3	0.1082	1.26	0.75	1.79*	0.131	--	"
2488	0.857	13.6	0.1130	1.25	0.77	2.01	0.092	0.12	"
2495	0.905	11.2	0.1142	1.28	0.78	1.74	0.109	--	"
2478	0.915	2.2	0.1136	1.27*	0.89	2.08	0.201	--	"
2482	0.917	1.6	0.1071	1.35	0.79	2.99*	0.277	0.10	"
2485	0.919	25.3	0.1183	1.27	0.83	2.21	0.060	0.10	"
2498	0.921	21.7	0.1196	1.29	0.97	1.78	0.088	0.08	"
2496	0.958	8.4	0.1229	1.34	0.80	2.68	0.130	--	"
2494	0.971	13.1	0.1363	1.37	0.84	2.47	0.102	0.14	"
2500	1.013	7.8	0.1728	1.36	0.77	3.53	0.051	--	"
2484	1.016	0.4	0.1686	1.32	0.71*	2.45"	0.091*	--	"
2479	1.025	.0	0.1792	--	--	--	--	--	"
2491	1.043	5.5	0.1810	1.39	0.73	3.53	0.040*	--	"
2492	1.043	6.3	0.1776	1.37	0.75	2.66*	0.094	--	"
2481	1.073	1.0	0.1880	1.40	0,79	4.77	0.065	0.17	"
2480	1.080	0	0.1868	--	--	--	--	--	"
2486	1.082	15.2	0.1921	1.37	0.79	2.80	0.028*	0.08	"
2487	1.104	5.8	0.1872	1.35	0.76	3.30	0.050*	0.12	"
2502									
2574	1.199	1.7	0.1692	1.50	0.75*	4.73*	-.138*	--	75mm
2576	1.324	1.0	0.1634	1.45	0.89*	3.72*	-.135*	--	"
2577	1.524	13.8	0.1668	1.45	1.03	4.90	-.083	--	"
2575	1.609	16.5	0.1642	1.44	0.95	4.54	-.089	--	"
2530	1.887	165	0.2449	0.84*	2.6	--	--	--	"
2578	2.153	211	0.2440	1.11	1.45	3.13*	-.07 *	--	"
2531	2.161	181	0.2451	1.07*	1.26*	2.01*	-.03 *	--	"

The usual statistical errors of the coefficients for this program are given below. An asterisk in the Table indicates that a particular value marked exceeds the usual value,

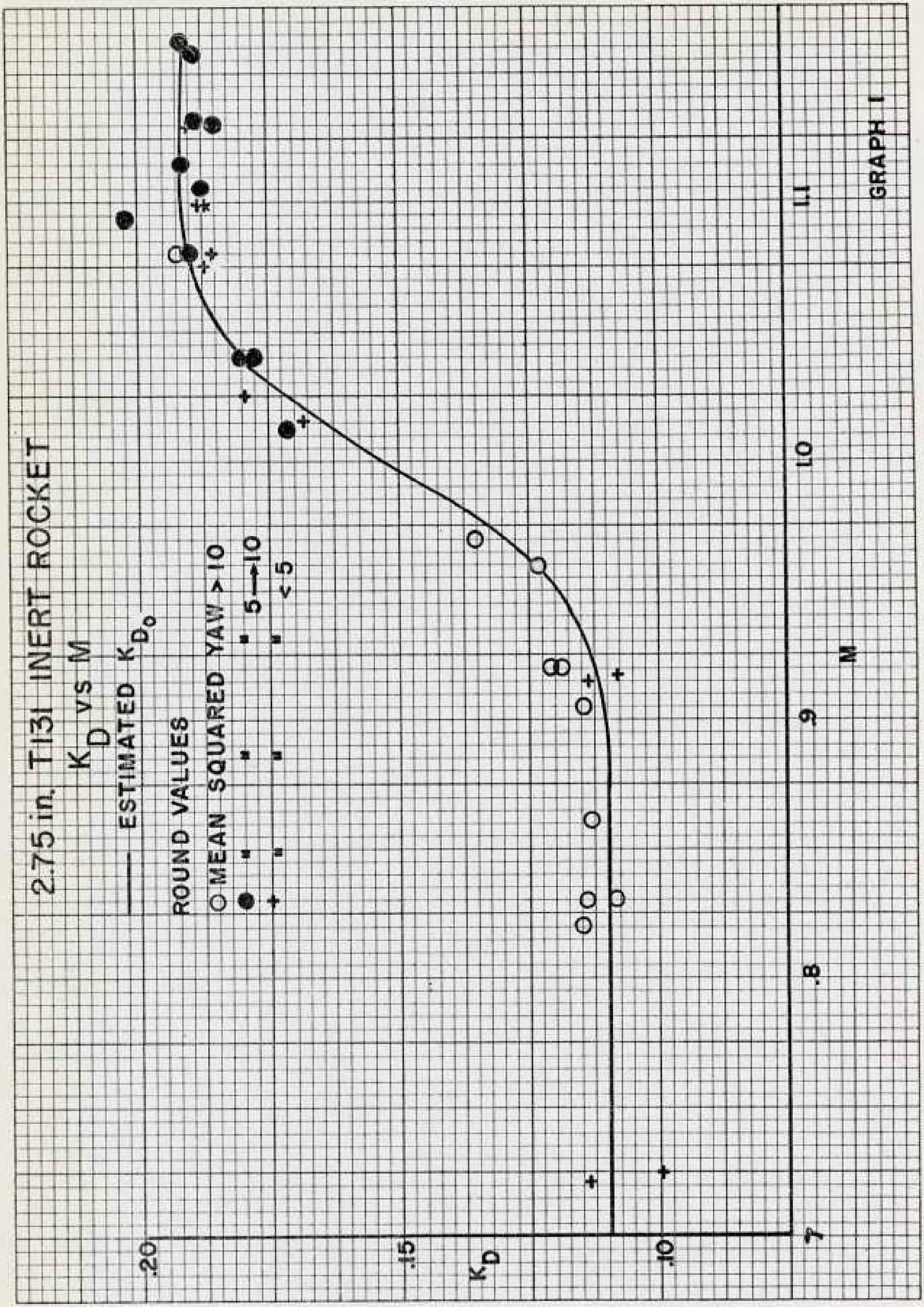
Coefficient	% Error
K_D	1/2 %
K_M	1 %
K_L	5 %
K_H	10 %
K_T	15 %
K_F	25 %

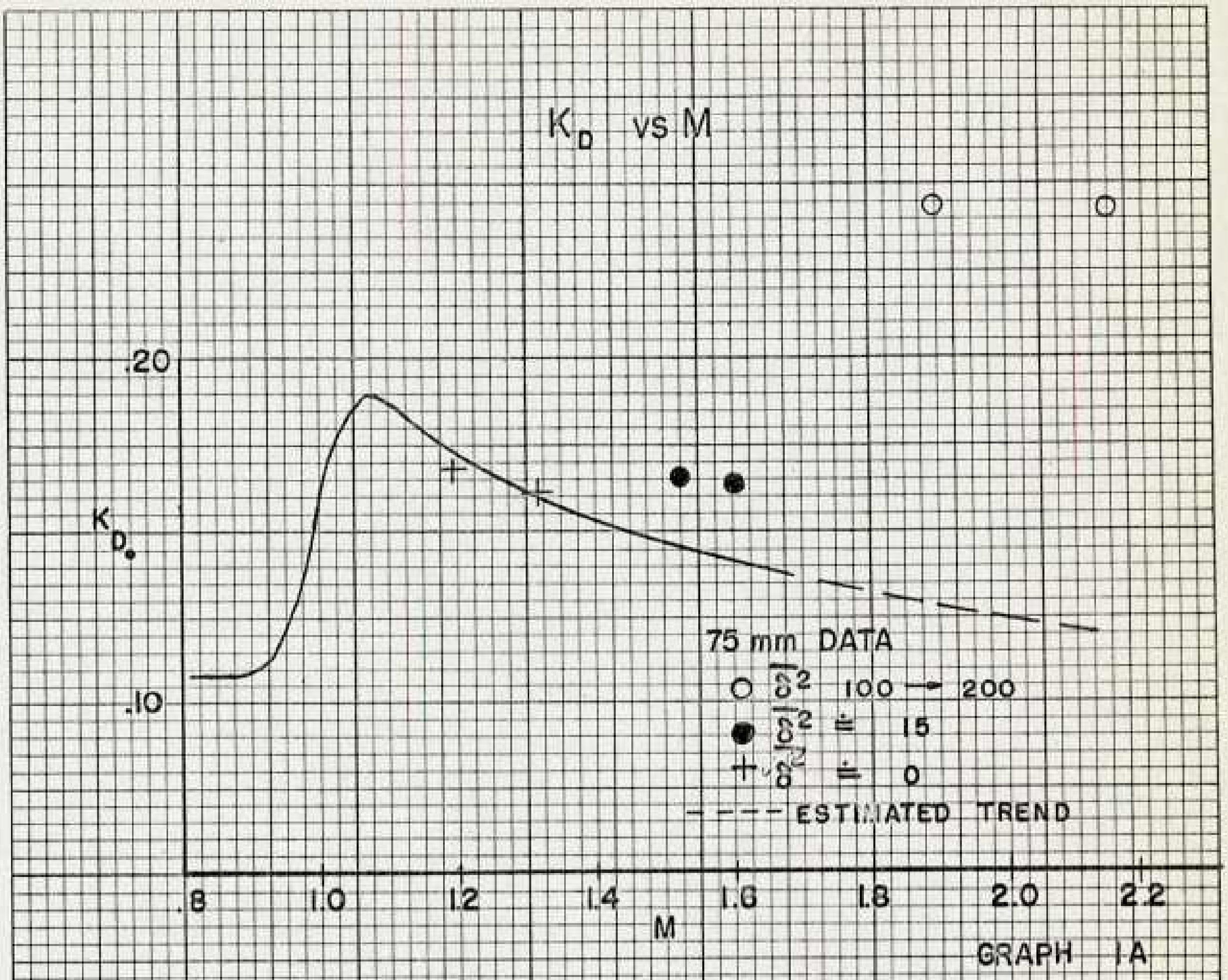
4.2

TABLE 5

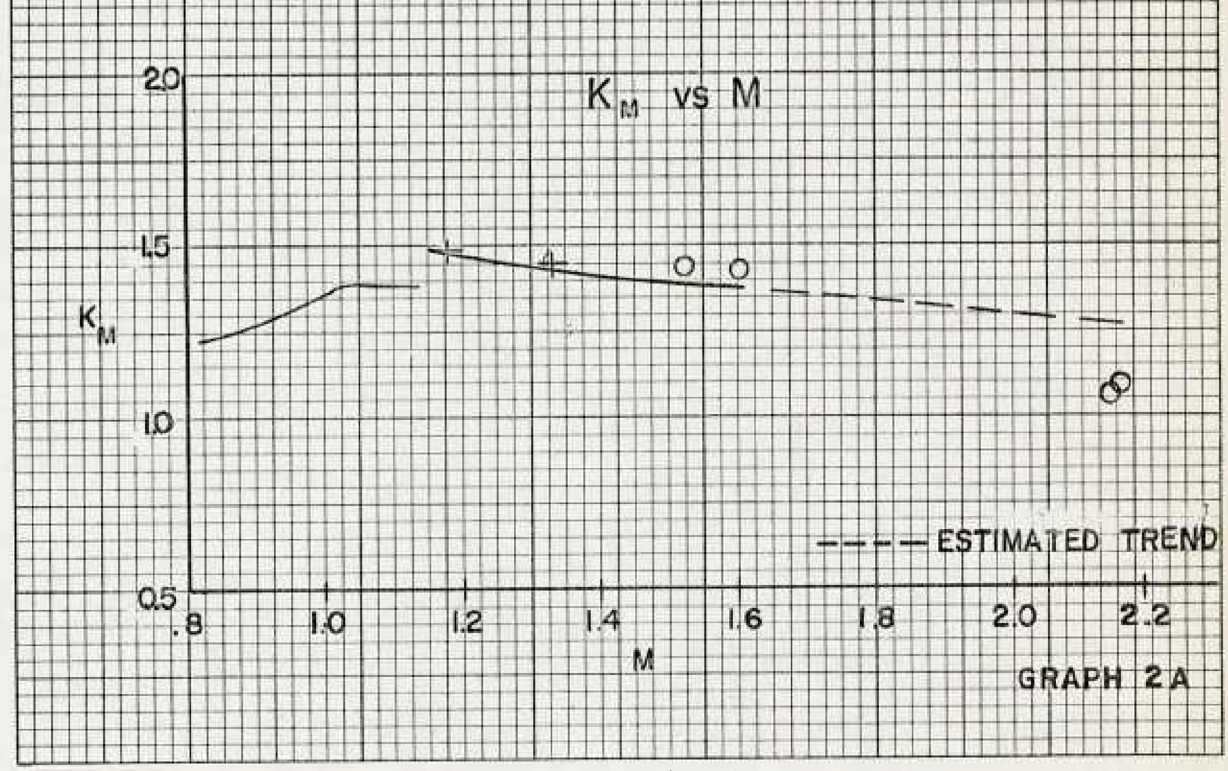
SUPPLEMENTAL DATA 2.75" ROCKET

Round No.	M	$\overline{\delta^2}$ deg^2	K_D	K_M	K_L	K_H	K_T	K_F	c.g. in from base
3391	1.08	7.3	.1896	1.140	0.747	4.15	0.048	--	5.471
3392									
3393	1.09	5.3	.2031	1.132	0.751	3.86	0.045	0.17	"
3390	1.11	9.2	.1922	1.125	0.751	3.95	1.037	0.12	"
3387	1.13	1.5	.1899	1.157	0.782	3.64	0.059	--	"
3388	1.16	8.4	.1916	1.173	0.820	4.55	-0.011	--	"
	1.13	6.8	.1902	1.140	0.755	4.05	0.030	0.12	"
	1.10	4.6	.1884	1.097	0.742	3.27	0.077	--	"
3386	1.10	3.8	.1884	1.643	0.814	3.11	0.063	--	4.179
3385	1.13	$\doteq 0$	.1899	--	--	--	--	--	"
3389	1.16	9.4	.1901	1.577	0.789	2.58	0.051	--	"

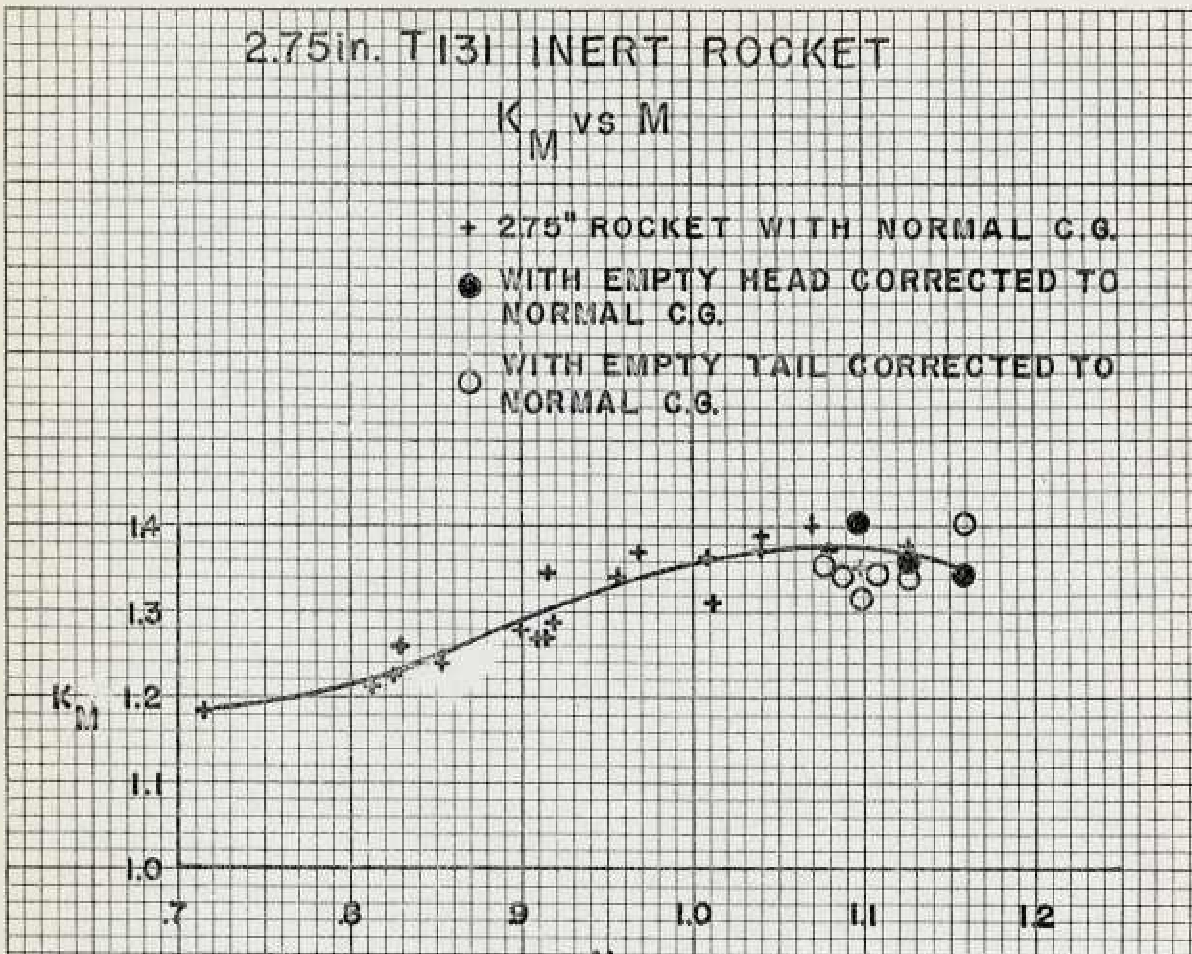

2.75 in. T131 INERT ROCKET
K_D vs M
— ESTIMATED K_{D_o}
ROUND VALUES
○ MEAN SQUARED YAW > 10
● " " " 5 → 10
+ " " " < 5
.20
.15
K_D
.10
.7
.8
.9
M
1.0
1.1
GRAPH I



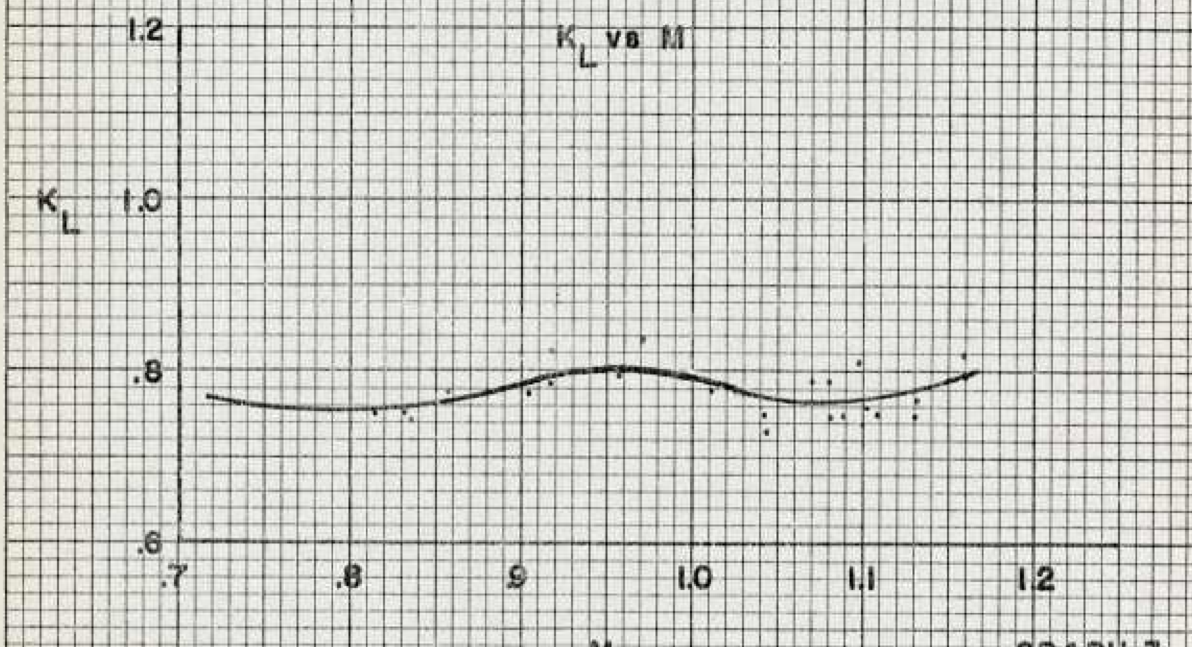
K_D vs M
.20
.10
K_D0
75 mm DATA
○ δ̄² 100 → 200
● δ̄² ≐ 15
+ δ̄² ≐ 0
---- ESTIMATED TREND
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
M
GRAPH 1A



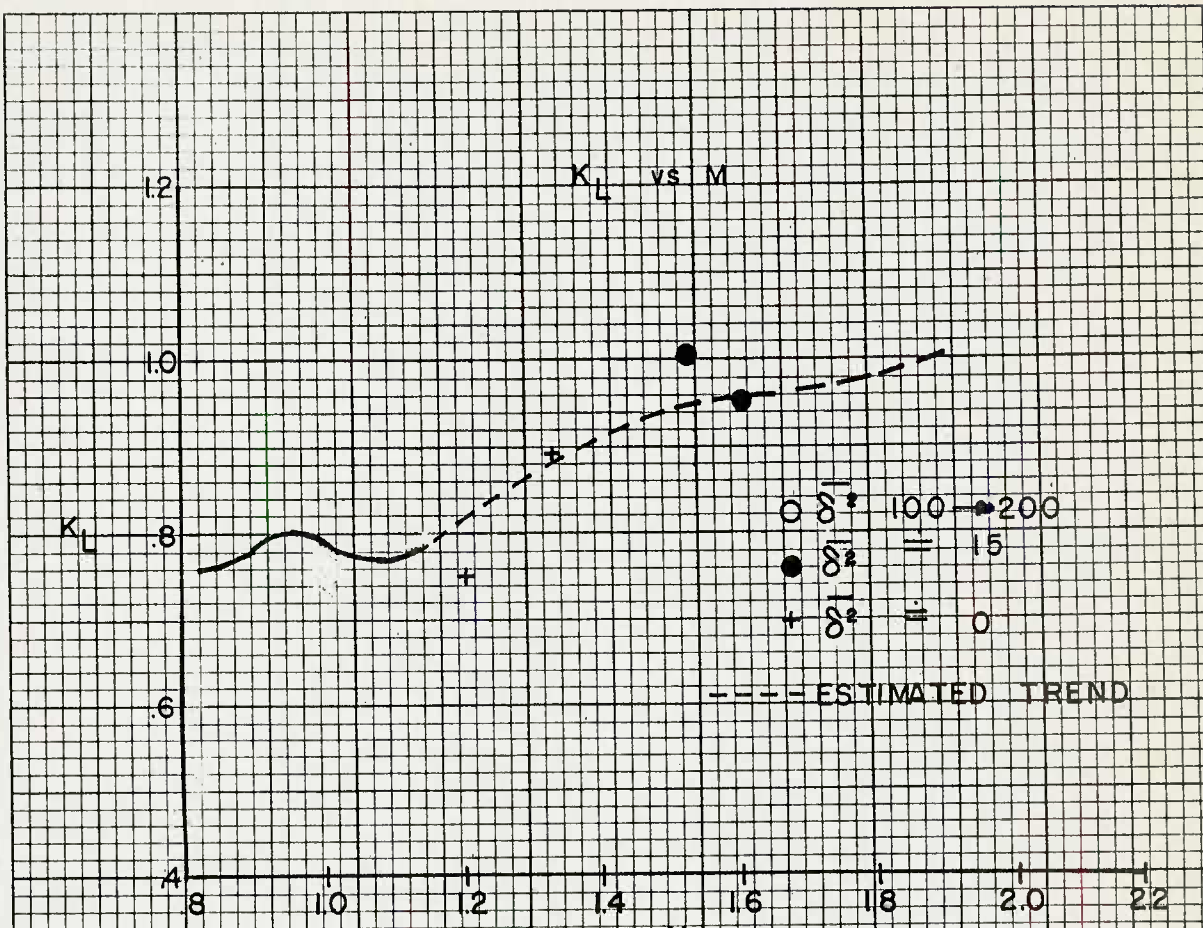
K_M vs M
2.0
1.5
1.0
0.5
K_M
---- ESTIMATED TREND
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
M
GRAPH 2A



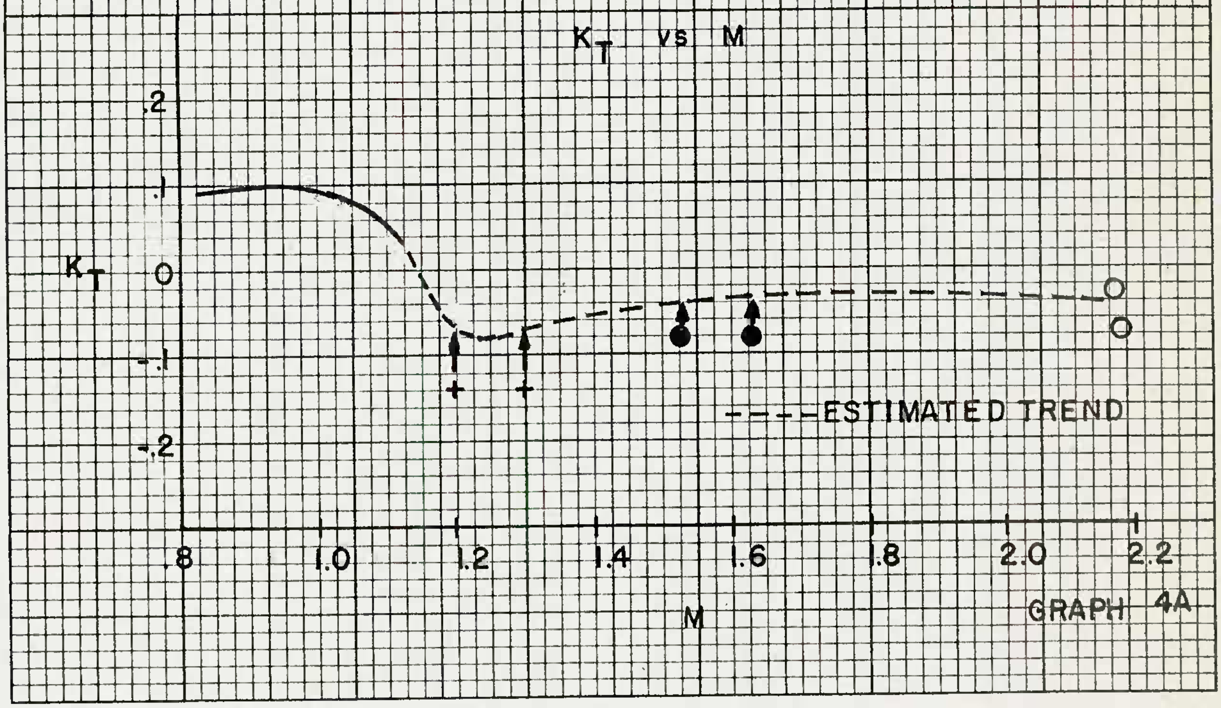
GRAPH 2



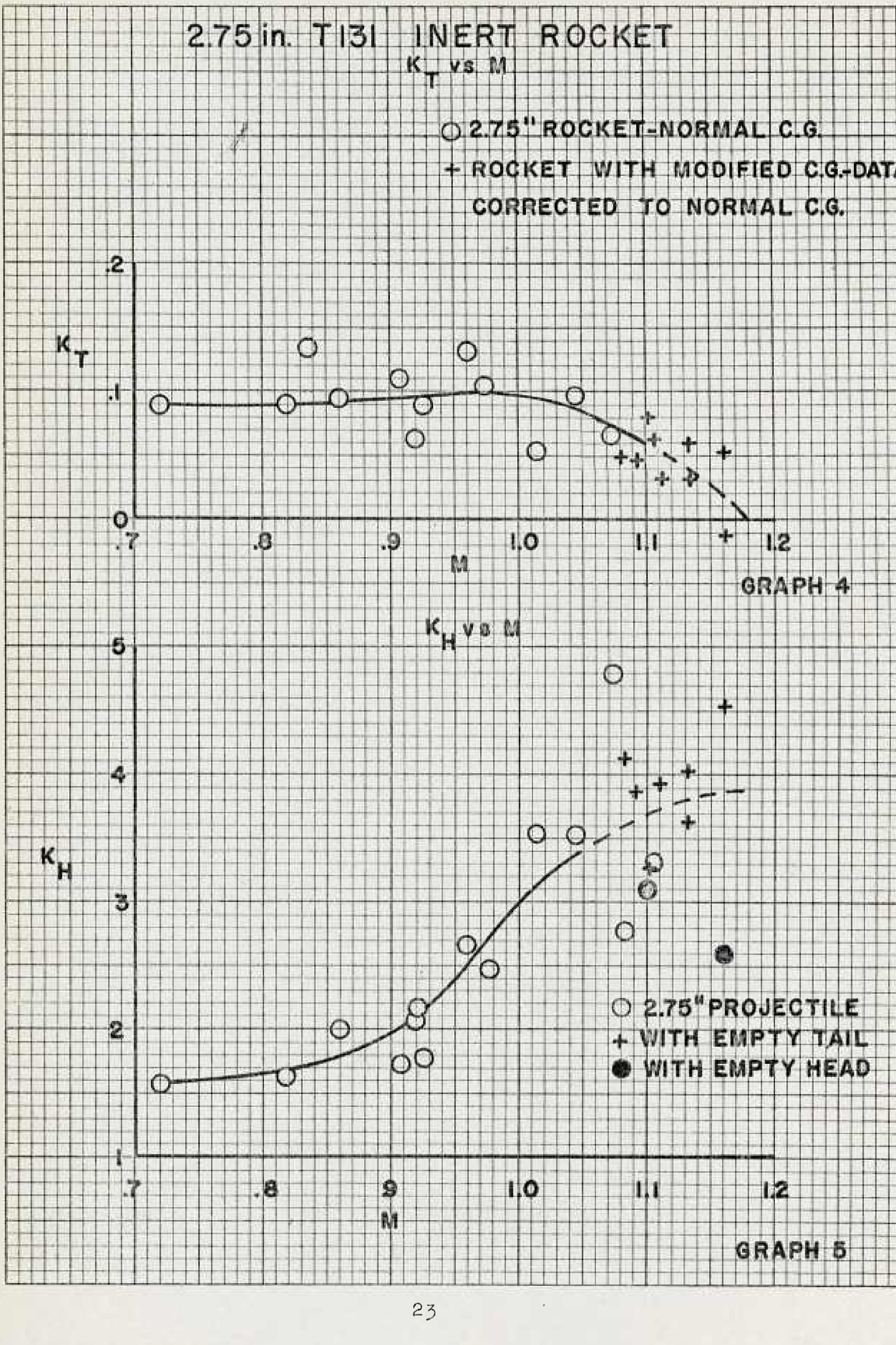
GRAPH 3



GRAPH 3A



GRAPH 4A



2.75 in. T131 INERT ROCKET
K_T vs M
○ 2.75" ROCKET-NORMAL C.G.
+ ROCKET WITH MODIFIED C.G.-DATA CORRECTED TO NORMAL C.G.
K_T
.2
.1
0
.7
.8
.9
1.0
1.1
1.2
M
GRAPH 4
K_H vs M
K_H
5
4
3
2
1
.7
.8
.9
1.0
1.1
1.2
M
○ 2.75" PROJECTILE
+ WITH EMPTY TAIL
● WITH EMPTY HEAD
GRAPH 5

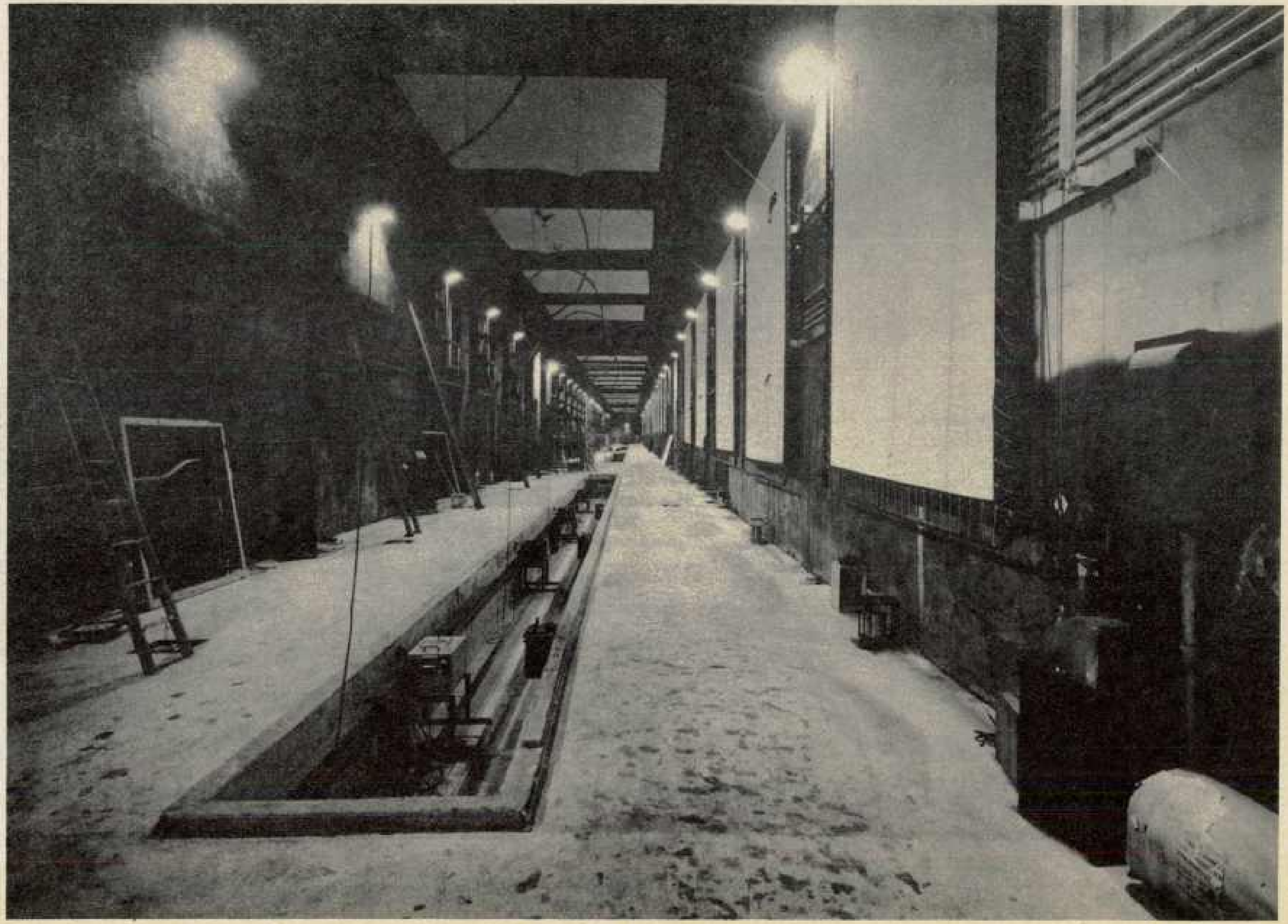


FIG. 1. Interior of Transonic Range.

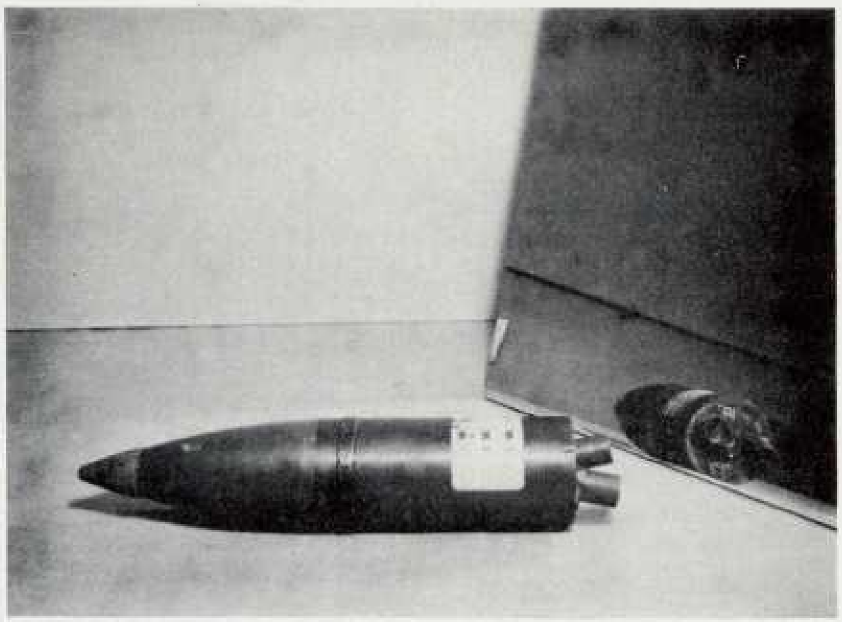


FIG. 2. 2.75 Inch T131 Projectile.

FIG. 3. Rocket Launcher Mounted on 155mm Howitzer Carriage.

FIG. 4. Rocket Launcher with Blast Deflector on Muzzle.

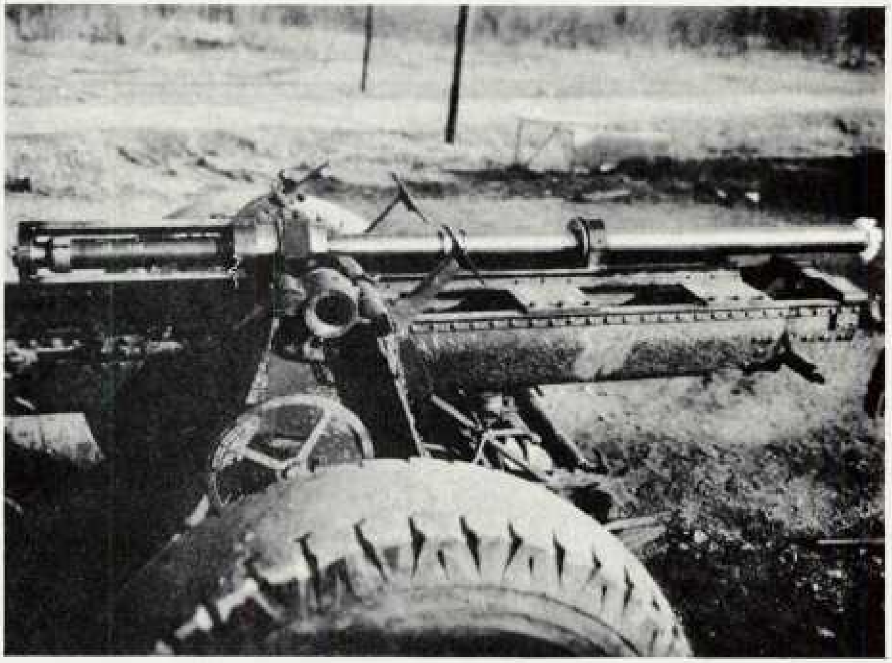


FIG. 5. Close-up, Launcher Breech.

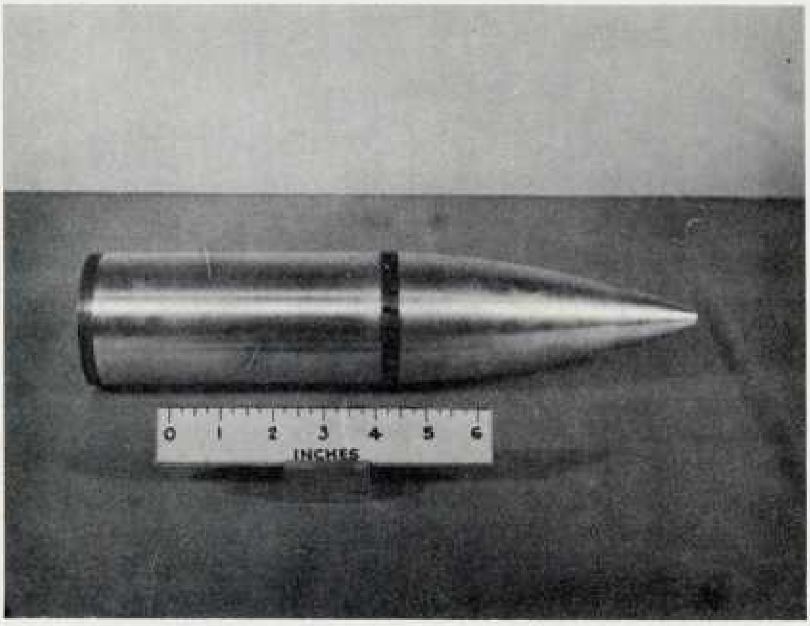


FIG. 6. 75mm Ballistic Slug of the T131 Rocket Shape.

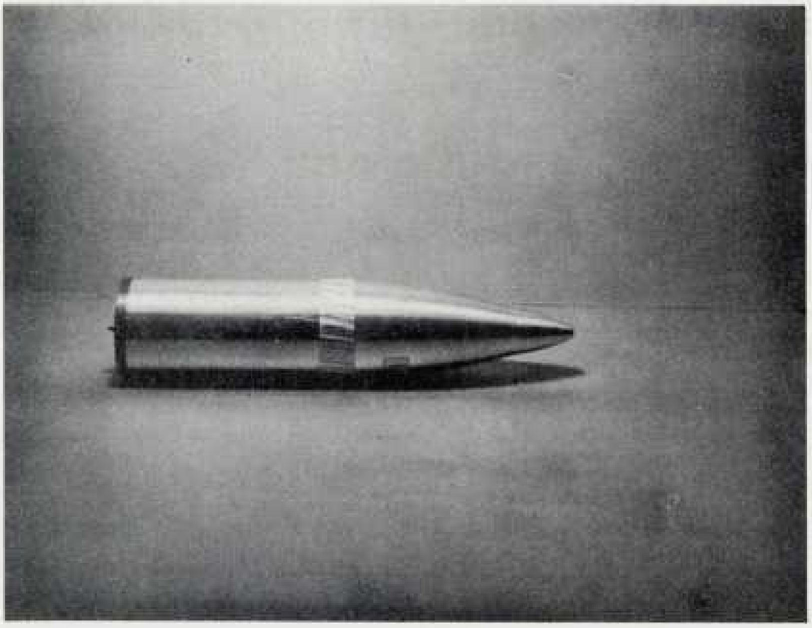


FIG. 7. Modified 75mm Ballistic Slug.

FIG. 8. 75mm M1A3 Howitzer.

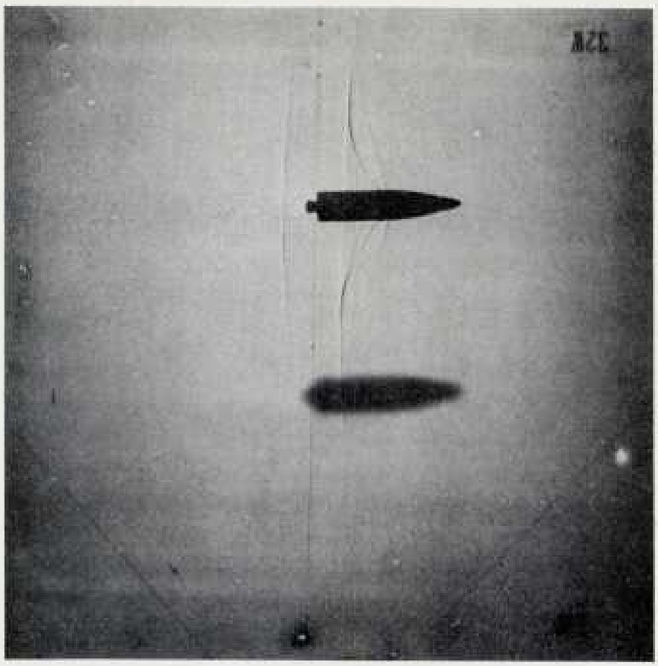


FIG. 9. Rocket in Free Flight (Round No. 2494)
Velocity: Approx. 1115 ft/sec.
Mach No. Approx. .99

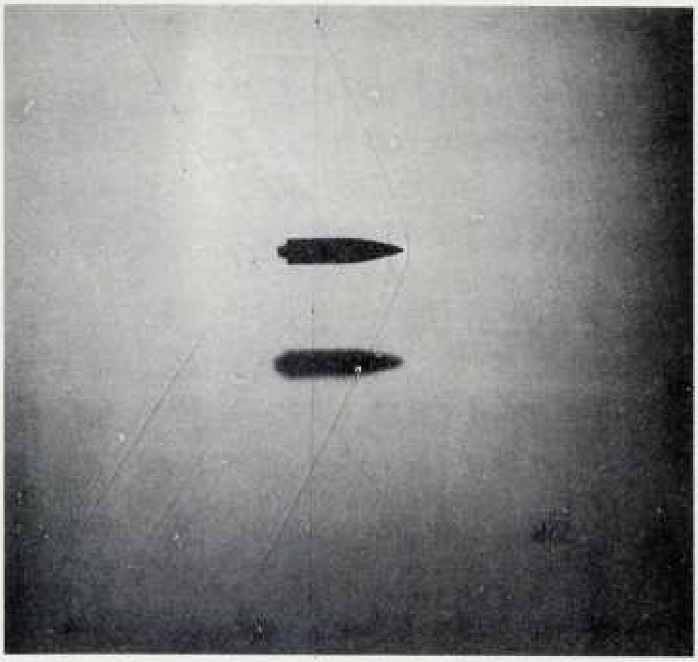


FIG. 10. Rocket in Free Flight (Round No. 2487)
Velocity: Approx. 1280 ft/sec.
Mach No. Approx. 1.14

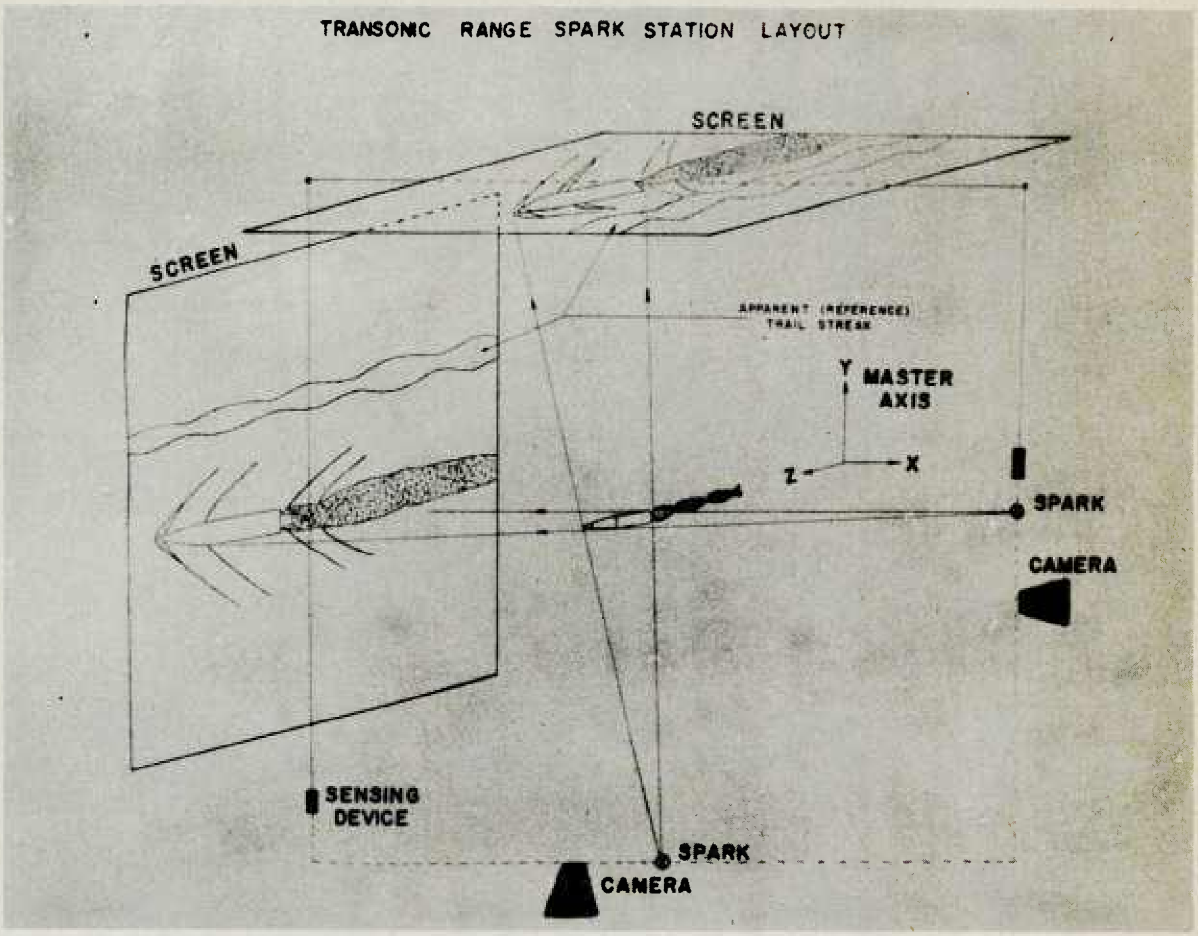


FIG. 11. Schematic Diagram of Range. Set-up for Live Rocket Spark Photography.

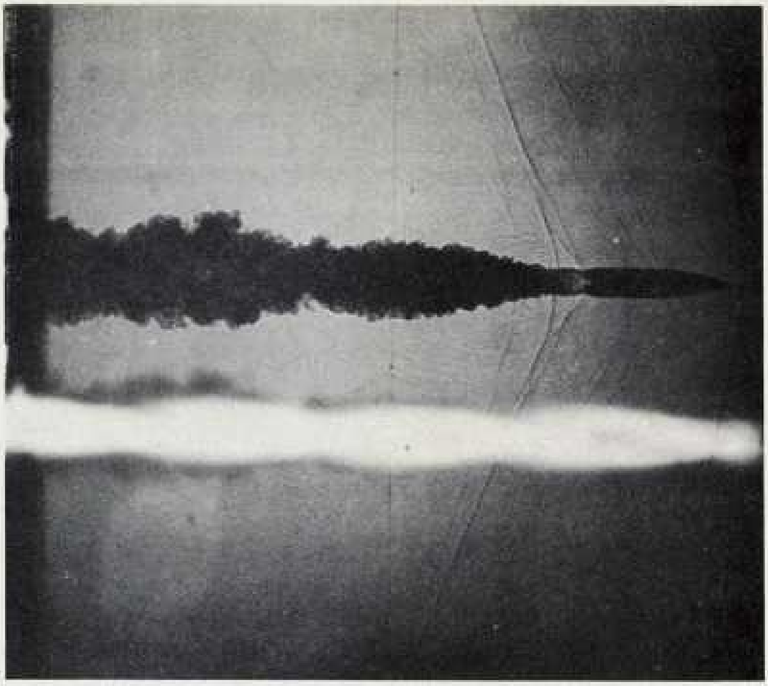


FIG. 12. Rocket in Burning Flight (Round No. 2506)
Distance from Launcher: Approx. 102 ft.
Velocity: Approx. 1205 ft/sec.
Mach No. Approx. 1.07

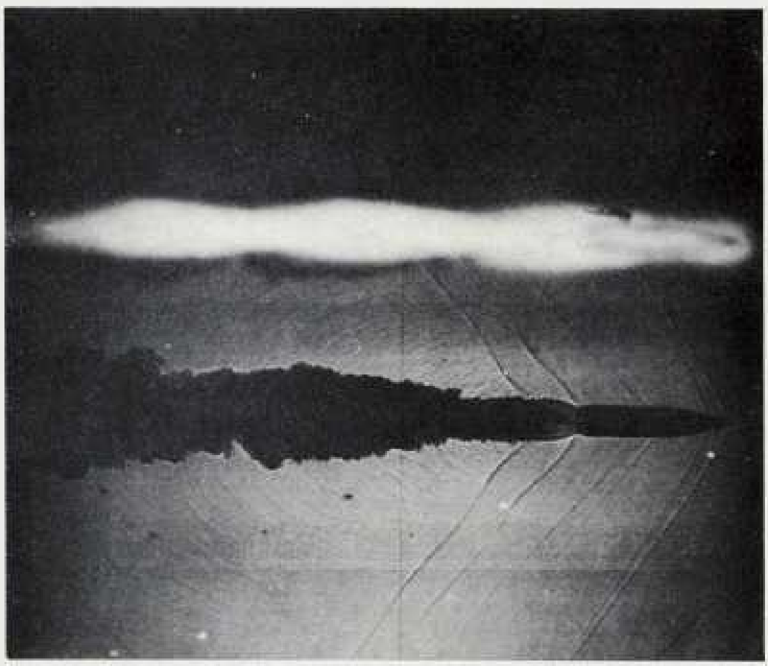


FIG. 13. Rocket in Burning Flight (Round No. 2506)
Distance from Launcher: Approx. 232 ft.
Velocity: Approx. 1440 ft/sec.
Mach No. Approx. 1.28

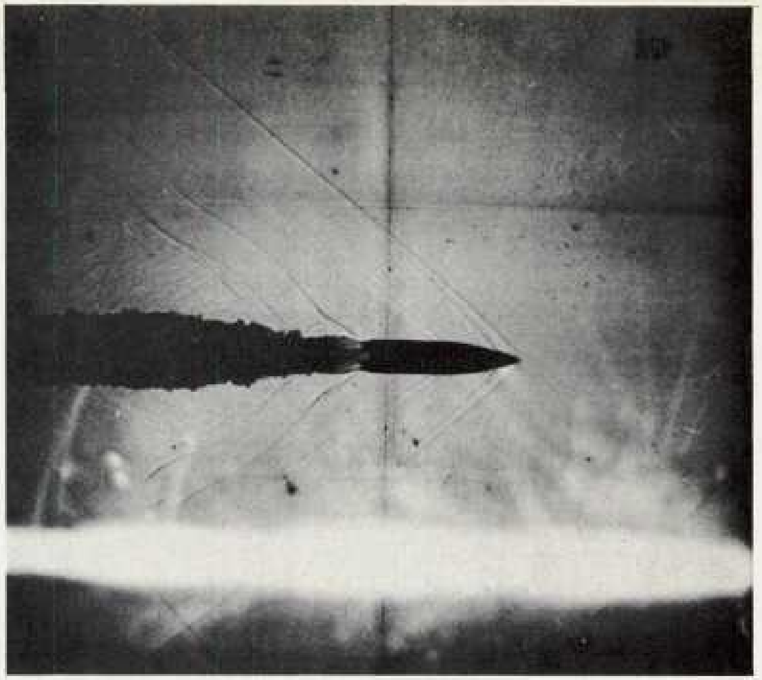


FIG. 14. Rocket in Burning Flight (Round No. 2506)
Distance from Launcher: Approx. 612 ft.
Velocity: Approx. 1875 ft/sec.
Mach No. Approx. 1.67

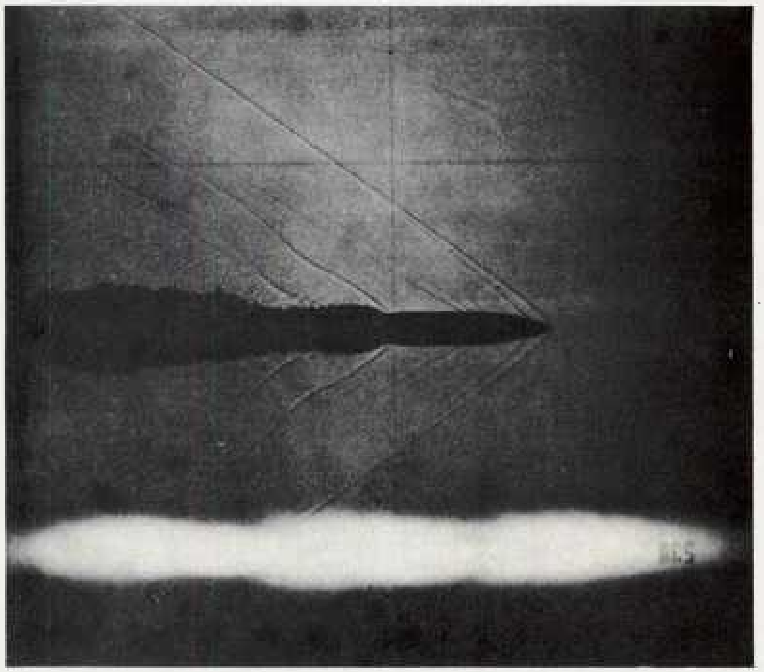


FIG. 15. Rocket in Burning Flight (Round No. 2506)
Distance from Launcher: Approx. 722 ft.
Velocity: Approx. 2036 ft/sec.
Mach No. Approx. 1.81

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4.5 REFERENCES

(1) Rogers, Walter K., "The Transonic Free Flight Range," BRL Report 849, (1953).

(2) Murphy, C.H., "Data Reduction for the Free Flight Ranges," BRL Report 900, (1954).

(3) Schmidt, L.E., Murphy, C.H., "The Aerodynamic Properties of the 7-Caliber AN Spinner Rocket in Transonic Flight, BRLM 775, (1954) (C).

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